CRITICAL CARE NURSING COURSE
BROOKE ARMY MEDICAL CENTER
FORT SAM HOUSTON, TEXAS 78234

Mechanical Ventilation

Objectives

1. Terminal Learning Objective

   Troubleshoot the mechanical ventilator.

2. Enabling Learning Objectives

   a. Discuss the major indications for mechanical ventilation.

   b. Discuss the types of mechanical ventilators in use today.

   c. Discuss the modes of mechanical ventilation.

   d. Discuss parameters to include tidal volume, respiratory rate, fraction of inspired oxygen, PEEP, CPAP, and Peak inspiratory pressure.

   e. Discuss high and low alarms.

   f. Discuss complications of mechanical ventilation.

   g. Discuss titration parameters.

   h. Discuss factors that impede weaning from mechanical ventilation.

NOTES

A. Indications for Mechanical Ventilation

1. Objectives of mechanical ventilation

   a. Improve pulmonary gas exchange

      (1) Reverse hypoxemia

(2) Relieve acute respiratory acidosis

b. Relieve respiratory distress

(1) ↓ work of breathing

(2) Reverse muscle fatigue

c. Alter pressure-volume relations

(1) Prevent and reverse atelectasis

(2) Improve compliance

(3) Prevent further injury

d. Permit lung and airway healing

e. Avoid complications

2. Major indications for mechanical ventilation

a. Impending or existing respiratory failure

b. After major surgery

c. Therapeutic hyperventilation in the presence of intracranial hypertension

3. Two types of respiratory failure

a. Hypoxemic - $PaO_2 < 60$ mm Hg (failure to oxygenate)

b. Hypercapnic - $PaCO_2 > 50$ mm Hg with pH $\leq$ 7.25 (failure to ventilate) - demands exceed supply

c. Three components

(1) CNS

(2) PNS - innervating the muscles of ventilation

(3) Airways

Hypoxemic Respiratory Failure
↓
Physiologic Shunt
↓
Stimulates the respiratory drive

No interface between ventilation
and pulmonary capillary.

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4. Disease processes heading to respiratory failure

a. Impaired alveolar ventilation - unable to adequately ventilate alveoli

↑ $paCO_2$ ↓ pH

(1) Chronic obstructive pulmonary disease

Example: emphysema, bronchitis, asthma, cystic fibrosis

(2) Restrictive pulmonary disease

Example: pleural effusion, pneumothorax, obesity

(3) Neuromuscular defects

Example: Guillian Barre, myasthenia gravis, multiple sclerosis

(4) Depression of respiratory control centers

(a) The $PaCO_2$ is always elevated in direct relationship to the degree of hypoventilation. Although hypoventilation may lower the PaO_2, it usually does not result in inadequate O_2 transport since the shape of the oxyhemoglobin dissociation curve allows the SaO_2 to remain close to normal.

(b) Hypoxemia caused by hypoventilation will respond to supplemental oxygen

(c) To ↓ the $PaCO_2$ the alveolar ventilation must be increased by the following means

Pulmonary hygiene, reversal of narcotics, mechanical ventilation

b. Diffusion disturbances - oxygen unable to transfer across the alveolar/capillary membrane

(1) Pulmonary fibrosis

(2) Pulmonary edema

(3) Adult respiratory distress syndrome

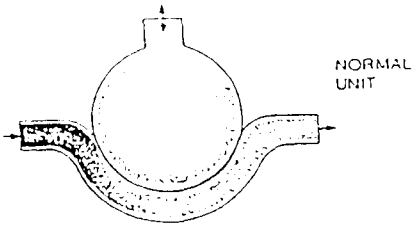
(4) Anatomic loss of functioning lung tissue

Example: tumor, pneumonectomy

NOTE: Will not cause hypoxemia unless it is very severe.

5. Ventilation (V) or perfusion (Q) disturbances.

a. Four possible V/Q relationships exist

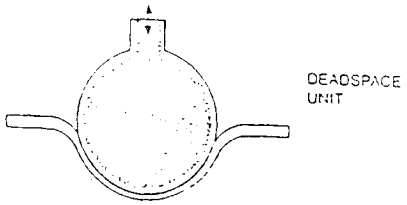


Alveolus

Capillary

Ventilation and perfusion relatively equal.

b. Dead space unit



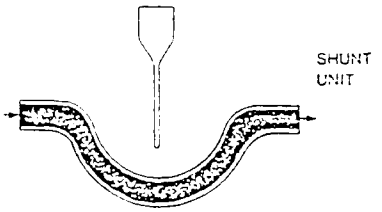
Alveolus

Alveolus is ventilated.

No blood flow through capillary = no perfusion.

Ventilation > Perfusion

c. Shunt

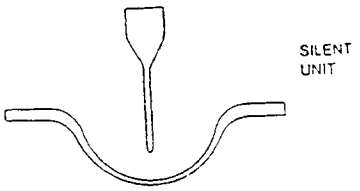


Alveolus is not ventilated. Perfusion occurs, but will not get past obstruction.

V < Q

Results in blood going from right heart to left heart without gas exchange taking place.

d. Silent Unit - No ventilation/no perfusion. Both alveolus and capillary are collapsed.



6. Examples of ventilation or perfusion disturbances

a. Pulmonary emboli

b. Atelectasis

c. Pneumonia

d. Emphysema

e. Chronic bronchitis

f. Acute respiratory distress syndrome

Ventilation (V) = 4L/min
Perfusion (Q) = 5L/min

$\frac{V}{Q} = 0.8$

< .8 = ↓ V or ↑ perfusion

> .8 = ↑ V or ↓ perfusion

B. Physical Assessment in a Patient with Acute Deterioration of ABG's

1. Tracheal shift

If the trachea is not in midline position suspect a pneumothorax

2. Asymmetric breath sounds

a. Pneumothorax

b. Right mainstem intubation

c. Mucus plugging with atelectasis

3. Wheezing

a. Bronchospasm

b. Mucus plugging

c. Pulmonary edema

d. Pulmonary thromboembolism

4. Bilateral decreased breath sounds

a. ET occlusion

b. Ventilator malfunction

c. Loss of airway

C. Types of Mechanical Ventilation

1. Volume-cycled: cycles to end inspiration and begin expiration when a predetermined volume is delivered

2. Time cycled - inspiration ends and expiration begins after a predetermined time interval has been reached

3. Pressure-cycled: inspiration ends and expiration begins when a predetermined maximal airway pressure is reached

D. Mechanical Ventilator Modes/Settings

1. Assist control - the ventilator delivers a preset number of breaths at a preset tidal volume. Between these machine-initiated breaths, the patient may trigger spontaneous breaths. When the ventilator senses the patient's spontaneous effort, it delivers a breath at the preset tidal volume. Indicated when an individual has a normal respiratory drive but respiratory muscles are too weak.

2. Synchronized Intermittent Mandatory Ventilation (SIMV) - the patient is guaranteed a preset number of breaths at a preset tidal volume. Between these mandatory breaths, the patient may initiate spontaneous breaths. The volume of spontaneous breaths is dependent on the muscular respiratory effort that the patient is able to generate. Indicated when the patient has normal respiratory drive but respiratory muscles unable to perform all the work of breathing. Desired when want to allow the patient to set their own rate. Also used in weaning patients from mechanical ventilation --> ↓ ventilation rate --> patient must ↑ their own rate.

3. FiO2 (Fraction of Inspired Oxygen) - the percentage of oxygen delivered to the patient. Example: Room air 21% oxygen.

4 Tidal Volume - the volume of gas moved into and out of the lung in a simple normal inspiration or expiration. Average: 5-8 ml/kg

5 PIP (Peak Inspiratory Pressure) - amount of pressure generated to deliver prescribed tidal volume. ↓ compliance ↑ PIP

6 PEEP (Positive End Expiratory Pressure) - application of a constant, positive pressure in the airways so that, at end-expiration, the pressure is never allowed to return to atmospheric pressure. Measured in cm of H2O. The benefit is ↑ recruitment of alveoli --> ↓ atelectasis. Complications of PEEP include barotrauma and decreased cardiac output due to compression of great vessels.

7 CPAP (Continuous Positive Airway Pressure) - positive pressure applied throughout the respiratory cycle to a spontaneous breathing patient. Patient must have reliable ventilatory drive.

8 Pressure support - a mode of ventilation in which the patient's respiratory effort is augmented by the delivery of a preset amount of inspiratory positive pressure. Pressure support is primarily used as a mode of weaning.

Pressure Support with PEEP

PSV	PEEP
↓	↓
Inspiration	Expiration
↓	↓
Supports Ventilation	Supports Oxygenation
↓	↓
↓ Work of Breathing	Opens Collapsed Alveoli
↓	↓
↑ Patient comfort	↑ FRC
↓	↓
Promotes Endurance Conditioning	Improves V/Q
	↓
	Improves oxygenation

PSV with SIMV

↓ the resistance of the ET tube and

↓ the work of breathing on the spontaneous breaths only

PSV with SIMV with PEEP

SIMV ensures adequate minute ventilation

PSV - ↓ work of breathing on spontaneous breaths

PEEP - recruits collapsed alveoli, improves V/Q ratios, and supports oxygenation. PEEP occurs on both spontaneous and machine breaths

E. Troubleshooting Alarms

1. High pressure alarms

a. Increased airway resistance

(1) Increased secretions - patient needs suctioning

(2) Kinks in ventilator circuitry -check circuits

(3) Water/secretions in circuits - empty circuits

(4) Patient bucking vent - may need sedation

(5) Patient biting ET tube - bite block

(6) Bronchospasm - bronchodilators

b. Decreased lung compliance

(1) Pneumothorax

(2) Pulmonary edema

(3) Atelectasis

(4) Worsening of underlying disease process

2. Low pressure alarms

a. Patient disconnected from machine - reconnect

b. Leak in cuff

Insufficient air - minimal air leak method. Inflate cuff. While auscultating neck withdraw air until you notice as slight leak on auscultation. Have pressure check by Respiratory Therapy using Wright's spirometer.

c. Leak in circuitry - check connections

d. ET Tube above vocal cords - confirm breath sounds. May need CXR.

e. Loss of air source

F. Complications of Mechanical Ventilation

1. Pulmonary

a. Barotrauma

b. Ventilator induced lung injury

c. Nosocomial pneumonia

d. Pulmonary thromboembolism

e. Tracheal stenosis

f. Tracheomalacia

2. Cardiac

   a. Myocardial ischemia

   b. Decreased cardiac output - especially with PEEP due to ↑ intrathoracic pressure pressing on great vessels

3. Gastrointestinal

   a. Ileus

   b. Hemorrhage

   c. Pneumoperitoneum

4. Renal - fluid retention

5. Nutrition

   a. Malnutrition

   b. Overfeeding

6. Psychological problems

G. Weaning Parameters

Minute Ventilation	≤ 10 L/min	Tidal volume X respiratory rate. Ensures adequate tidal volume.
Negative Inspiratory Force	≥ -20cm HE	Maximum negative pressure patient is able to generate to initiate breath.
Tidal Volume	5-10 ml/kg	Indicates patient's ability to initiate inspiration independently.
FIO2	≤ 0.40	Appropriate for patient's baseline.
ABG's		

H. Factors That May Impede Weaning

1. Malnutrition

2. Electrolyte Disturbances

   a. Hypokalemia

   b. Hypomagnesemia

   c. Hypocalcemia

   d. Hypophosphatemia

   e. Metabolic acidosis

   f. Metabolic alkalosis

3. Increased resistance to airflow

   a. Airflow obstruction

   b. Small endotracheal tube

   c. Secretions

4. Thyroid abnormalities

5. Medications

   a. Sedatives

   b. Narcotics

   c. Paralytics

6. Generalized weakness

7. Anemia

8. Limited left ventricular reserve

9. Systemic infection
10. Fever
11. Renal dysfunction
12. Hemodynamic instability
13. CNS disorders
    a. AMS - altered mental status
    b. Pain
    c. Anxiety
14. GI disorders
    a. Ileus
    b. Ascites
    c. Constipation
    d. Diarrhea